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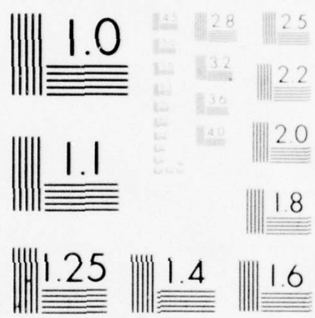

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PROGRAM MANAGEMENT COURSE
INDIVIDUAL STUDY PROGRAM

PATROL FRIGATE
PROPULSION SYSTEM
LAND BASED TEST SITE:
PROTOTYPE OR SIMULATOR

PMC 74-1

THOMAS A. BEYER
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BEYER

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) (6) PATROL FRIGATE PROPULSION SYSTEM LAND BASED TEST SITE: PROTOTYPE OR SIMULATION.		5. TYPE OF REPORT & PERIOD COVERED (9) Student Project Report, 74-1
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) THOMAS A. BEYER		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS DEFENSE SYSTEMS MANAGEMENT COLLEGE FT. BELVOIR, VA 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (11) May 74
11. CONTROLLING OFFICE NAME AND ADDRESS DEFENSE SYSTEMS MANAGEMENT COLLEGE FT. BELVOIR, VA 22060		12. REPORT DATE 1974-1
		13. NUMBER OF PAGES 56 (12) 58p.
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

SEE ATTACHED SHEET

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

DEFENSE SYSTEMS MANAGEMENT SCHOOL

STUDY TITLE:

PATROL FRIGATE PROPULSION SYSTEM LAND BASED TEST SITE: PROTOTYPE OR SIMULATOR

STUDY GOALS:

To identify criteria which may prove useful to furture major weapon systems acquisitions.

STUDY REPORT ABSTRACT

The purpose of this study is to analyze alternatives to full scale prototyping. The proposed Land Based Test Site (LBTS) for the Patrol Frigate (PF) propulsion system was used as a model. The model was compared to a simulator which consisted of a student console, a computer, and an instructor's console. Each alternative was evaluated in relation to the stated objectives for the LBTS. After identifying differences in meeting the objectives of the LBTS the evaluation was reviewed for purposes of identifying criteria which could prove useful to furture programs.

KEY WORDS: MATERIEL ACQUISITION PROPULSION SYSTEMS PATROL SHIPS FRIGATES MATERIEL DESIGN AND DEVELOPMENT PROTOTYPES INTEGRATED LOGISTICS SUPPORT SYSTEMS ANALYSIS

NAME, RANK, SERVICE	CLASS	DATE
Thomas A. Beyer	PMC-74-1	May 16, 1974

PATROL FRIGATE PROPULSION SYSTEM
LAND BASED TEST SITE:
PROTOTYPE OR SIMULATOR

An Executive Summary
of a
Study Report
by

Thomas A. Beyer
GS-12 U.S. Navy

May 1974

Defense Systems Management School
Program Management Course
Class 74-1
Fort Belvoir, Virginia 22060

EXECUTIVE SUMMARY

The purpose of this study is to analyze alternatives to full scale prototyping. The proposed Land Based Test Site (LBTS) for the Patrol Frigate (PF) propulsion system was used as a model. The model was compared to a simulator which consisted of a student console, a computer, and an instructor's console. Each alternative was evaluated in relation to the stated objectives for the LBTS. After identifying differences in meeting the objectives of the LBTS the evaluation was reviewed for purposes of identifying criteria which could prove useful to future programs.

The conclusions indicate that there are numerous considerations which must be made in evaluating the need for a prototyping effort. System analysis and decision analysis are two tools which could be used successfully to ensure completeness of considerations. These eight criteria were particularly apparent.

1. Justify the prototype in engineering terms.
2. Assess the cost and schedule risk of developing the prototype in terms of the benefits.
3. Select the objectives with extreme care.
4. Review current testing for applicability.
5. Analyze all possible alternatives.
6. Consider ILS early.
7. Assess the management risk.
8. Consider political issues.

PATROL FRIGATE PROPULSION SYSTEM
LAND BASED TEST SITE :
PROTOTYPE OR SIMULATOR

STUDY REPORT

Presented to the Faculty

of the

Defense System Management School

in Partial Fulfillment of the

Program Management Course

Class 74-1

by

Thomas A. Beyer

GS-12 U.S. Navy

May 1974

CONTENTS

Chapter I

INTRODUCTION:

The cost of major weapon systems has doubled over the past ten years. The Department of Defense (DOD) is modernizing their acquisition procedures in order to reduce these costs. One of the areas receiving extensive high level interest is the identification and reduction of technical risks. To this end, DOD will not permit a program to progress into the Full Scale Production phase until they are satisfied the risk has been minimized. In a majority of cases this results in a need to prototype and debug weapons prior to production.

Shipbuilding; because, of its long construction period is seriously handicapped with this philosophy. In compliance with the need to reduce technical risk only advanced technological areas need be prototyped. Advanced technological areas are difficult to identify in many cases and prototyping may be applied when not truly necessary. The purpose of this paper will be to identify criteria which may be applied to determine if prototyping is indicated. The Patrol Frigate Propulsion System has been selected for purposes of this investigation.

The Patrol Frigate Propulsion System is being constructed at a Land Based Test Site (LBTS) located at the Naval Shipyard in Philadelphia, Pennsylvania. The principle agent to the PF Project Manager is the Naval Ship Engineering Center Philadelphia Division (NAVSECPHILADIV). The PF

This study represents the views, conclusions and recommendations of the author and does not necessarily reflect the official opinion of the Defense Systems Management School nor the Department of Defense.

Project Manager will present the findings of their initial testing to the Defense System Acquisition Review Council (DSARC) in May of 1975. Under the limitations of this schedule the site is currently being constructed; and, the decision to enter full scale production will depend largely upon the performance of this site and a companion test facility for the combat system.

The literature and data to be researched for this investigation is provided through the author's two years of experience in the program office. The inputs establishing the requirements are taken from current DOD Directives (DODD) which are in effect. The program objectives have been established by the program office and are the same for purposes of this study.

The study will be organized into six chapters in addition to the Introduction. Chapters II and III will deal with the related research and data collection which provide the inputs for this systems analysis. These chapters describe how the data has been obtained, its significance to the research question and how it will be used. Chapters IV and V will consist of a description of two alternatives, which could satisfactorily reduce the technical risk. Chapter VI will consist of the analysis performed on the two alternatives. In Chapter VII I will include additional research considerations, and the utility of the criteria.

I intend to limit this analysis to two alternatives. The possibility of combining alternatives will not be considered in the interest of brevity; however, combined alternatives may prove fruitful ground for future investigations. In order to bring the subject into a work package which can be handled within the time constraints of this project; the

parameters to be considered will consist of Technical Support, Integrated Logistics Support (ILS), Test and Evaluation (T&E), Schedule, and Costs. A rigorous analysis would normally include the Political, Psycho-Social, and Cultural parameters as well. These items will be addressed to the extent they will contribute to identifying the criteria sought.

Since the PF propulsion system has been selected for investigation it is appropriate to consider the objectives of this system for purposes of this analysis. The hypothesis is that if the alternatives which are being considered can satisfy these goals they are indeed viable alternatives. The objectives are identified in the PF Propulsion System LBTS Management Plan(1)* as follows:

PRIMARY OBJECTIVES:

Prior to February 1975 the primary objective of the Land Based Test Site is to support the production decision for follow on ships. After February 1975 the LBTS objectives will be to verify operating, maintenance and test procedures; to provide additional operational training, and to test system upgrading.

SECONDARY OBJECTIVES:

In conjunction with the primary objectives the following secondary objectives are to be realized during the entire life of the LBTS:

1. To verify the basic design of the propulsion system prior to shipboard installation.

* Superscript numbers in parentheses refer to references listed at the end of this report. See the Table of Contents for page numbers.

2. To verify initial component check out and test procedures.

3. To verify installation procedures as appropriate.

4. To provide the baseline for configuration management of the shipboard equipment.

5. To evaluate selected maintenance procedures.

6. To verify logistics support requirements as appropriate.

7. To determine the adequacy of propulsion controls.

8. To determine the level of machinery monitoring required for proper system operation and maintenance.

9. To verify operating procedures for normal and casualty modes.

10. To evaluate proposed changes to the shipboard propulsion system prior to commitment to the entire class.

11. To provide a continual input into the PF test and evaluation.

METHODOLOGY:

In the analysis I will evaluate the following alternatives:

1. FULL SCALE PROTOTYPING - This alternative consists of using the actual shipboard equipment which will make up the propulsion system.

2. PROPULSION SYSTEM SIMULATION - The propulsion system simulator will provide a sophisticated class room training aid capable of reacting in a manner similar to the actual propulsion system. The simulator will consist of three components; (1) the student control console, (2) the instructor's control console, and (3) a computer which is programmed to simulate the propulsion system. The instructor will activate an abnormal condition expected to occur at sea. The student will react to the abnormal condition by taking corrective action at the student control console. The computer will process the data from both sources and

respond with the appropriate data which will be representative of the propulsion system responses under similar conditions.

Figure I-1 is a flow diagram which provides the general outline for the evaluation. After the Technical Support, ILS, T&E, Schedule and Cost characteristics have been evaluated for each alternative the objectives will be reviewed to determine if they have been satisfied. If it is found that all of the objectives have not been satisfied, consideration will be given to compromising some of the objectives. The impact of any compromised objectives will be analyzed in full; but, in no event will the primary objective of supporting a production decision be relaxed. Alternatives which satisfy the objectives will be screened for criteria and will be included in the summary. I expect that this procedure will result in the identification of considerations which can be applied for future DOD programs.

The primary constraints of this analysis are schedule and costs. The costs constraints which are referenced in this analysis are the costs of full scale prototyping. The prototyping costs should result in the largest expenditure and may be considered a maximum. The schedule is constrained by the DSARC III date which requires light-off of the prototype operation by 23 December 1974.

The general orientation to the main ideas of this paper is not intended to impute, in any way, the decisions which have been made during the development of the Patrol Frigate. There should be no question that looking back on decisions will surface many shortcomings. The purpose of this writing is to analyze the decisions which were made; to determine if they stand the test of investigation. Hopefully the results of the

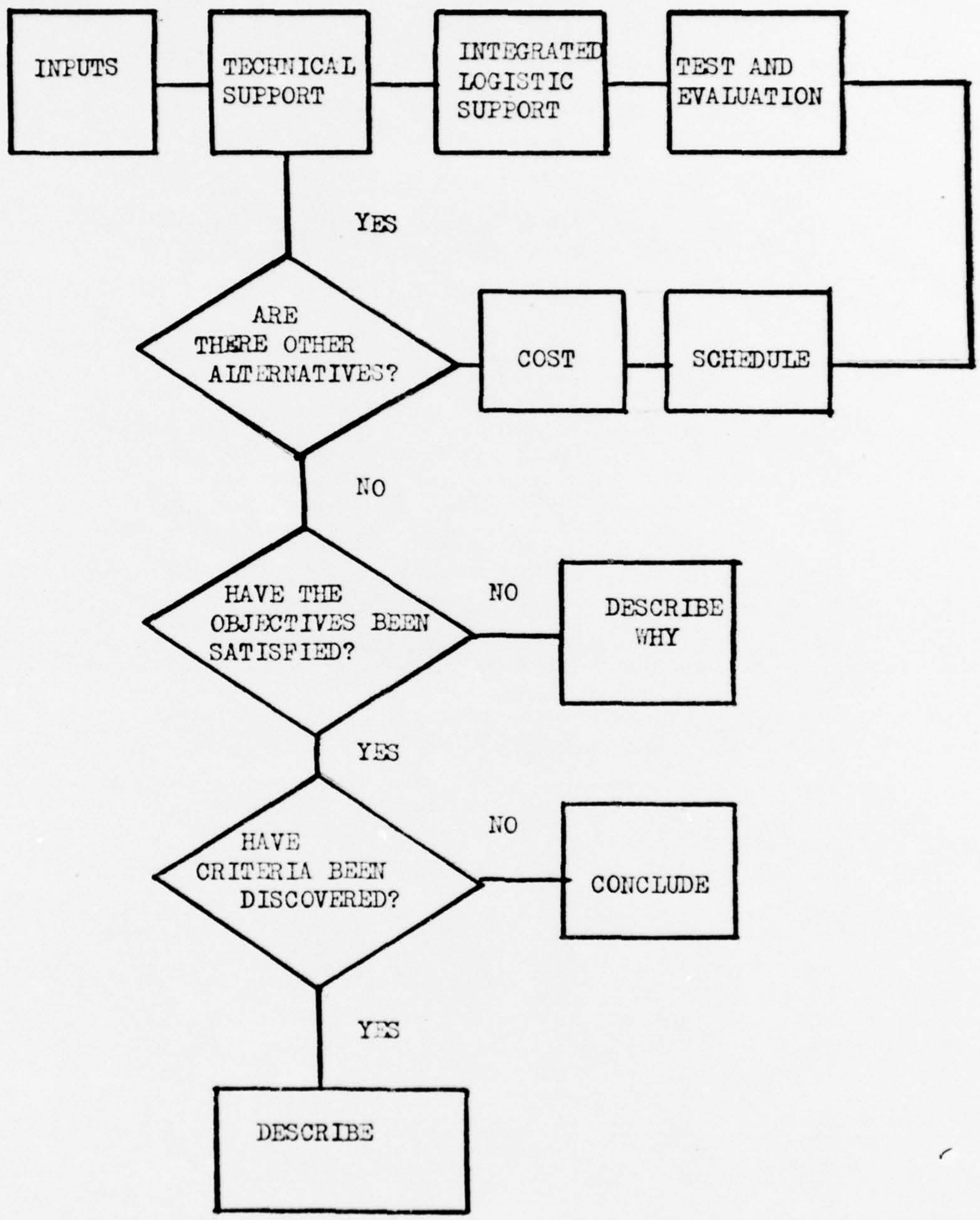

INPUTS
TECHNICAL SUPPORT
INTEGRATED LOGISTIC SUPPORT
TEST AND EVALUATION
YES
ARE THERE OTHER ALTERNATIVES?
COST
SCHEDULE
NO
HAVE THE OBJECTIVES BEEN SATISFIED?
NO
DESCRIBE WHY
YES
HAVE CRITERIA BEEN DISCOVERED?
NO
CONCLUDE
YES
DESCRIBE

FIGURE I-1

analysis will yield criteria which may assist future Program Managers in dealing with the risk associated with technical uncertainty.

Chapter II

REVIEW OF RELATED LITERATURE:

A constant expansion in the numbers of dollars required to support the Department of Defense has been steadily growing since the end of World War II. This trend has persisted although in terms of real purchasing power, the Fiscal Year 1974 spending for National Defense represents the lowest level of more than 20 years and the manpower level in DOD is less than any year since 1950[2]. A major portion of these costs can be directly attributed to the acquisition of weapons systems. A need to reduce DOD spending has been identified many times by the President and other government officials as well as concerned citizens.

The need to maintain our position of strength in the world has not diminished; however, our capabilities in relation to supporting an adequate military organization are under attack. The enemy is one which has been with us from the beginning--- money. Expanding technology provides the driving force which requires us to develop new and better weapons at an increased cost. The cost is not totally attributable to the technological factors since inflation, poor business practices and high development risks are also involved. The list is endless and the point to be made is clear. We must make better use of the diminishing number of dollars which will be available to us in the future. The DOD has taken an initial step by developing plans which will minimize the inefficiencies which currently exist in the field of weapons procurement.

On 13 July, 1971 Deputy Secretary of Defense: David Packard, created a major change in the DOD management by issuance of DODD 5000.1

"Acquisition of Major Defense Systems". This Directive recognizes that successful development, production and deployment of major defense systems are dependent on people, priorities and clearly defined responsibility. To this end, the policy invoked by this document results in making a single individual accountable for a major procurement. He shall have a charter with sufficient authority to accomplish his program objects and sufficient tenure to accomplish his task. The layers of management between the program manager and his service head will be minimized.

If a program results in an expenditure in excess of 50 million dollars for research and development, or is in excess of 200 million dollars during production and is urgent to National Security it will be classified as a major acquisition program. The program will be separated into four distinct phases which require approval by the Defense System Acquisition Review Council (DSARC) before being permitted to proceed into the next phase. The DSARC review process occurs at three decision point milestones during the normal life cycle of the system development. These are the transitional points between phases of the system acquisition:

1. DSARC I, occurs between the Conceptual and Validation phase.

2. DSARC II, occurs between the Validation and Full Scale Development phase.

3. DSARC III, occurs between the Full Scale Development and Production phase.

The life cycle phases for a normal weapon system development are:

Conceptual Phase: the objective of this phase is to define and select the system concept which warrants development.

Validation Phase: the objective of this phase is to validate the choice of alternatives and to provide a basis for determining whether or not to proceed into full scale development.

Full Scale Development: The objective of this phase is to provide a hardware model and the documentation needed to produce the system.

Production Phase: The objective of this phase is to produce the system for operational use.

Before a project can successfully pass the three DSARC decisions, it must: be well defined, be capable of being logistically supported, have minimized the technical uncertainty and have been properly tested. As stated in DODD 5000.3 "Test and Evaluation":

> "The long design, engineering, and construction period of a major ship will normally perclude completion of the lead ship and accomplishment of test therefore prior to the decision to proceed with follow ships. In lieu thereof, successive phases of Development Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E) will be accomplished as early as practicable at test installations and on the lead ship so as to rapidly reduce risks and thereby minimize the need for modification to follow ships"

This Directive goes on to say:

> "For new ship types incorporating major technical achievements not earlier proven in hull or non-nuclear propulsion design, a prototype incorporating these advancements will be employed. If the major technological advancements are contemplated in only some features of the hull or non-nuclear design, the test installation need incorporate only the applicable new features. Adequate test and evaluation on such prototypes will be completed prior to the first major production decision on follow ships"

The Patrol Frigate propulsion system falls into this classification. In order to satisfy the requirements of this Directive and 5000.1, the Program Manager has determined that the propulsion system for this ship should be prototyped at a Land Based Test Site (LBTS). Since it is far too difficult and expensive to exactly duplicate the engine spaces of the

ship, a considerable degree of license has been taken in the development of this facility. The intent of the Test and Evaluation Directive will be satisfied by this site; however, it will not be possible to validate all of the actual maintenance procedures due to the dissimilarity in the physical constraints between the ship and the test site.

The Department of Defense approach to systems acquisition has as a primary motive the reduction of costs. The thesis of this paper is that a careful look at systems which are intended to be prototyped be considered. In many instances when a prototype is developed, the technical risk is reduced; however, when these units go into production the same types of problems occur despite the prototype effort. This suggests that perhaps the technical uncertainty can be reduced in another manner which is less costly but equally effective. If successful this paper will identify criteria which can be applied during the Validation and Full Scale Development phases of a program that will help analyze the costly decision to enter into a prototyping effort.

Chapter III

DATA COLLECTION AND ANALYSIS:

As previously mentioned the model for this analysis will be the Propulsion System Land Based Test Site for the Patrol Frigate which will be located in Philadelphia, Pennsylvania. The participants for the design, construction and operation of the LBTS are presented here primarily to identify their contributions and the sources used to gather data. In terms of the analysis it is only necessary to indicate the need for the participants their identity is of little importance.

> Project Office - The primary agent responsible for ensuring that the design, construction, and operation of the test facility takes place within the approved budget and on schedule.
>
> Naval Ship Engineering Center (NAVSEC) - This is the Navy's primary technical support organization. They establish the Navy position in areas which require resolution on the basis of technical soundness. The final decision for the project in relation to the technical uncertainty remains with the Project Office.
>
> Naval Ship Engineering Center Philadelphia Division (NAVSECPHILADIV) - The Philadelphia Division is a laboratory operation devoted to the resolution of technical problems encountered in the fleet. They are hardware people with extensive experience in the test and evaluation areas. This organization is the PO's agent and custodian of the LBTS which is currently being erected at Philadelphia and is scheduled for light-off in December of 1974.
>
> Bath Iron Works (BIW) - BIW is the prime contractor to the Navy for the construction of the Patrol Frigate Lead Ship and the Propulsion System and Combat System LBTS. In terms of the PS/LBTS they are providing the main elements of the propulsion system through the efforts of their sub-contractors which are listed below for reference.
>
> > Gibbs and Cox (G&C) - Bath Iron Works principle design agents.

General Electric, Evondale (GE,E) - Gas Turbine engines and acoustic module.

Western Gear (WG) - Main reduction gear, clutches and brakes.

Bird-Johnson and Co. (BJCO) - Controllable Reversible Pitch (CRP) propeller and main shafting.

General Electric, Apollo (GE,A) - Main Control Console (MCC) and Local Operating Panel (LOP)

The Propulsion System Land Based Test Site will consist of the following equipment:

: Main Propulsion Units - Two GE, LM 2500 Gas Turbine engines

: Main reduction gear - One reduction gear complete with high speed clutches and brakes.

: Shafting and propeller - One CRP and shaft complete with the necessary hydraulics.

* : Waterbrake - One waterbrake energy absorber capable of absorbing 50,000 horse-power of energy.

: Control system - One control system which will consist of the Operators Panel, Local Operators Panel, and Bridge Control Console.

Intake and exhaust ducts - A complete system which simulates the actual ducting configuration intended for the ship.

: All other necessary support systems needed to operate the facility. (examples are Fuel Oil System, Fuel Transfer System, Lube Oil System, etc.)

* The Waterbrake is not intended for shipboard installation; but, is required to absorb the energy being developed by the main propulsion units when in operation.

Figure III-1 is an illustration of the PS LBTS. The equipment not being provided by BIW or their sub-contractors will be purchased by NAVSECPHILADIV. This includes all of the support equipment not previously mentioned.

The primary objective of the PS/LBTS for the PF is to provide the necessary support needed for the production decision. The PF DSARC III date, as of this writing, is scheduled for May 1975. Since the needed support information will be available for this review, it will be necessary to operate the system for some period of time prior to DSARC III and early enough to reduce the data which will be the input for the DSARC. A target of 500 hours of engine operation has been established which will require the system to light-off no later than December 1974. After May 1975 the plant will continue to operate in support of the stated secondary objectives. The May 1975 milestone date for the PS/LBTS is one of the most critical issues for a successful DSARC III. The second most critical issue is as always...cost.

The information for this analysis comes mainly from conversations with the principles and the "PF Propulsion System Land Based Test Site Management Plan"[1]. The approach to the analysis will begin with the establishment of an indenture level concept similar to a Work Breakdown Structure. The equipment being tested for the purposes of reducing the technical risk and the elements being considered for this analysis will form a matrix as shown on Figure III-2. The numbers that appear at the intersections of this matrix are descriptive of the alternatives under investigation. Squares which do not consider all of the alternatives represent shortcomings, in relation to the objectives.

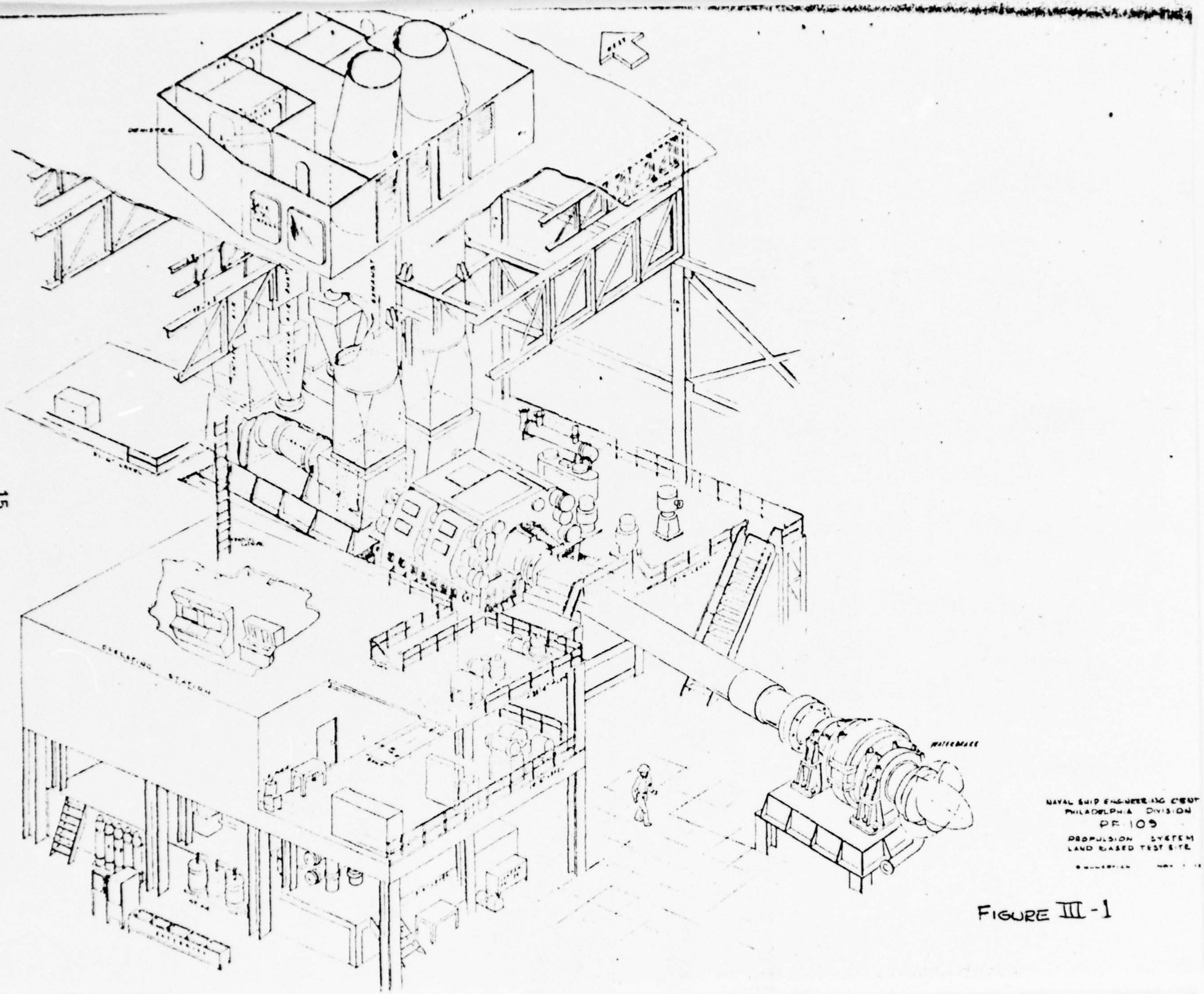

OPERATING STATION
WATERBRAKE
NAVAL SHIP ENGINEERING CENTER
PHILADELPHIA DIVISION
PF 109
PROPULSION SYSTEM
LAND BASED TEST SITE

FIGURE III-1

ELEMENT	EQUIPMENT				
	GT	RG	SHAFT	CRP	CONTR.
TECH. SUPPORT	I&II	I&II	I&II	I&II	I&II
ILS	I&II	I&II	I&II	I&II	I&II
T&E	I&II	I&II	I&II	I&II	I&II
SCHEDULE	I&II	I&II	I&II	I&II	I&II
COST	I&II	I&II	I&II	I&II	I&II

I FULL SCALE PROTOTYPE

II SIMULATOR

KEY:

GT	GAS TURBINE
RG	REDUCTION GEAR
CRP	CONTROLABLE PITCH PROPELLER
CONTR.	CONTROL SYSTEM

FIGURE III-2

The costs which are shown for the model are total costs for the PS/LBTS. They have been rounded off and represent an order of magnitude rather than an actual budgeted cost. A basic assumption is that the prototype costs will exceed the cost for the simulator. The costs for alternatives also represent an order of magnitude and are the results of an educated guess.

Chapter IV

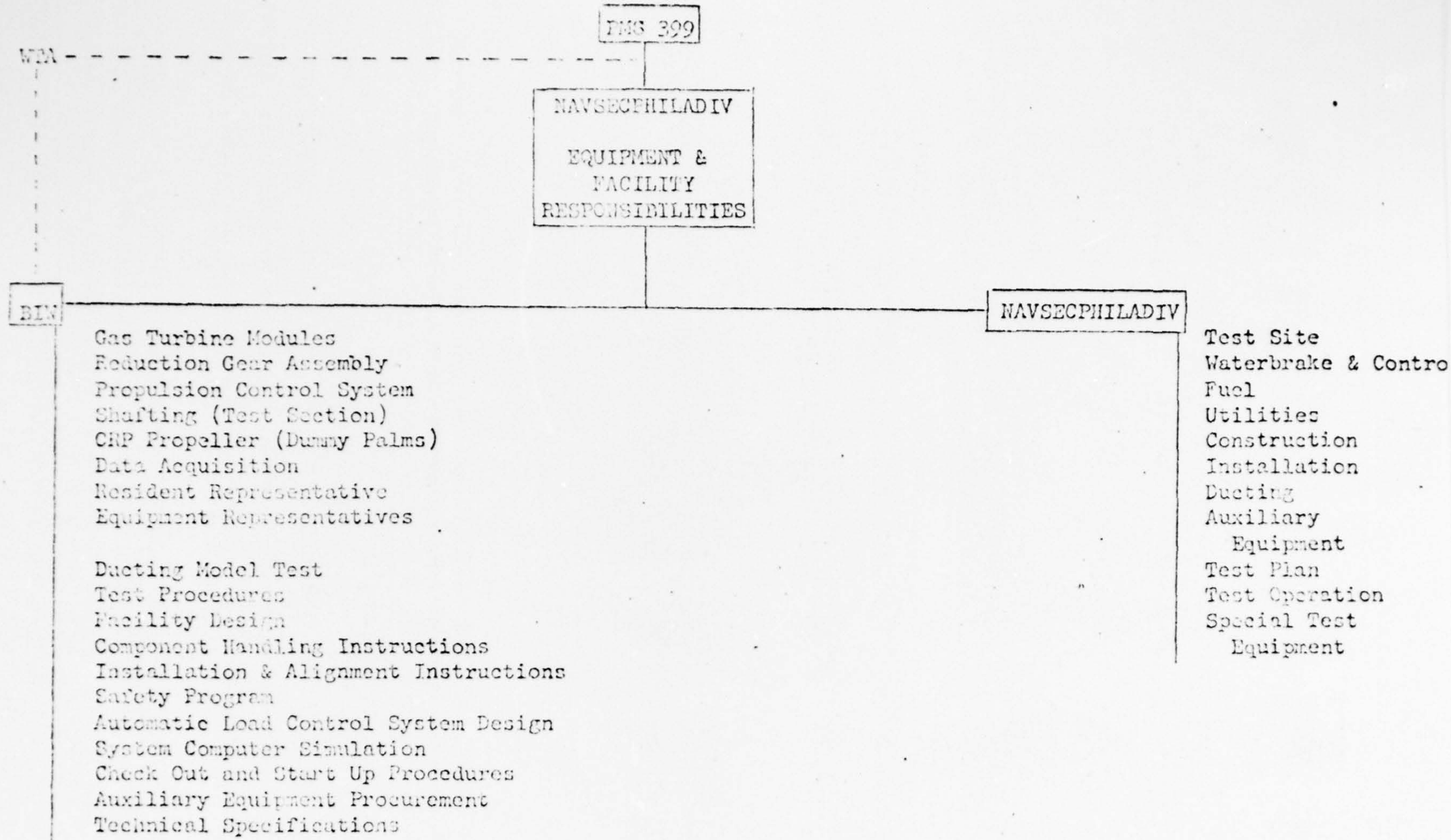
FULL SCALE PROPULSION SYSTEM PROTOTYPING:

Technical Support

The design of the facility by Gibbs and Cox, Inc. (G&C), a design subcontractor to Bath Iron Works, was accomplished in two phases. A site survey and inspection was conducted to determine preliminary machinery arrangement, equipment lists, safety program, duct design arrangement and the waterbrake load control system for phase I. Phase II will consist of the remaining design work required to complete the facility. The scope of the work to be completed by G&C during phase II consists of the following:

- Design drawings
- Component handling
- Installation and alignment instructions
- Component and system checkout
- Initial start up procedures
- Propulsion vibration studies
- Safety program
- Technical specifications for auxiliary equipment

Bath Iron Works (BIW) has the responsibility of procuring the major propulsion system components including spares for 90 days of operation and delivering them to NAVSECPHILADIV in accordance with the terms and space conditions of the Ship System Design (SSD) support contract. BIW and their subcontractors will also provide installation interface information and procedures in addition to the engineering services indicated in Figure IV-1. The responsibility for supplying



EQUIPMENT AND FACILITY RESPONSIBILITIES

FIGURE IV-1

the remainder of the auxiliary equipment belongs to NAVSECPHILADIV.

The facility construction will be handled by NAVSECPHILADIV working through the Naval Regional Procurement Office (NRPO) and the Shipyard Public Works organization. They will see to it that the site is cleared and upon receipt of approved design drawings from BIW/G&C will determine the best method for having the system constructed and installed. A determination will be made at that time in relation to doing the work in house or contracting the task to an outside agent.

The installation and assembly techniques are to duplicate the approach to be used by the shipyard (BIW) during erection of the lead ship to the extent practical. BIW is to provide specific written assembly instructions and alignment instructions. They are also expected to provide detailed handling instructions for each shipboard component encompassing all movement of the equipment from the time of its arrival through storage and final installation. Following the installation of each completed system and upon completion of the entire facility the system shall undergo a checkout procedure developed by BIW/G&C.

Integrated Logistics Support (ILS)

<u>Maintenance Planning</u> - The maintenance planning which has been done for PS/LBTS consists primarily of the planning necessary to provide logistics support for 3000 hours of test operation. There is a strong possibility that the LBTS will function as a training hot plant beyond the 3000 hours of operation; however, this is not funded under the PF appropriation.

Support and Test Equipment - With the exception of the Waterbrake which is necessary to absorb the power developed by the ships engines, all support equipment currently exists within the laboratory or is readily available. No special test and support equipment is anticipated for this testing effort.

Supply Support - Under the SSD contract BIW is required to provide spare parts for 90 days of operation. Beyond this initial 90 day period NAVSECPHILADIV will provide all spares needed for 3000 hours of test. A list of recommended spare parts is provided with each major piece of equipment shortly after it is ordered. The Government will review this list and order those parts which, on the basis of good engineering judgement, tempered with the manufacturer's recommendations, are necessary for successful completion of the test period. In the event the inventory becomes depleted, additional spares will be ordered on the basis of how much time remains in the test schedule and the frequency with which the failed or worn part requires replacement. Records will be kept by NAVSECPHILADIV of the kinds and amounts of spare parts used to maintain the major system components, controls and selected auxiliary equipments. This information will be used in determining the logistic requirements for the Patrol Frigate ships.

Transportation and Handling - As previously mentioned BIW is responsible for determining the transportation and handling instructions which will describe how the equipment is to be handled prior to installation. The equipment procured by BIW will be transported in a manner compatible with their contracts. Similarly NAVSECPHILADIV will arrange for all transportation and handling of the equipment for which they are

responsible.

Technical Data - The technical data, instructions, repair manuals and other documentation necessary to operate and maintain the shipboard equipment will be provided to NAVSECPHILADIV by BIW. NAVSECPHILADIV will arrange whatever documentation is necessary to support the equipment they provide. Installation procedures, checkout procedures, system operation procedures, and all other documentation required under the contract between BIW their subs and the Navy, (that is relative to the PS/LBTS) will be provided to NAVSECPHILADIV.

Facilities - As previously mentioned the facilities are provided by NAVSECPHILADIV. These facilities include oil storage tanks necessary to store the fuel used during the testing as well as all utilities, services, buildings, material handling equipment and office space.

Personnel and Training - The plan is to have an initial cadre of Naval personnel at the LBTS for training purposes throughout the testing period. Hands on operation is encouraged; however, the prime intention is to attest to the systems performance. Upon completion of the 3000 hours of the propulsion system testing, the LBTS facility will be utilized to provide training for future crew members. In conjunction with the Chief of Naval Training (CNT), NAVSECPHILADIV will develop a course curriculum and will conduct the PF and USN training program.

Logistic Support Resource Funds - The resources needed for ILS are included in NAVSECPHILADIV budget. The funds required to support the training effort for the LBTS are not included in the PF full scale development phase.

Logistics Support Management Information System - The information system for the LBTS is primarily an informal effort. Monthly and quarterly situation reports are developed and sent to the program office for review. A monthly meeting is conducted at Philadelphia to assess the latest progress and provide guidance to the participants. NAVSECPHILADIV maintains a library of data associated with the LBTS. BIW will establish a configuration control baseline of the propulsion system in accordance with the SSD support contract. An RMA assessment and failure analysis of the overall propulsion system will be made by NAVSECPHILADIV for comparison with BIW analysis which is provided for under the SSD contract.

Test and Evaluation

The overall operation and maintenance of the LBTS is the responsibility of NAVSECPHILADIV. Plant operations and maintenance will be conducted by Naval Personnel when appropriate. The test plan and agenda will be developed by the laboratory with component test procedures developed by BIW. An initial performance verification test will be conducted for approximately 500 hours to establish the performance baseline. This phase of the test will also act as a demonstration for DSARC to support the follow on ship program.

The remaining 2500 hours of testing will attest to the system capability to make speed, power, and maneuvering. Together with the initial 500 hours of testing, the plant will have been operated for a total of 3000 hours.

Following the 3000 hours of testing a final verification test will be conducted to determine what deviation from the original performance has taken place, if any. The data will also be used to predict future performance loss for comparison against the maintenance and logistics plan for the ships. All operational difficulties and equipment failures will be fully documented and submitted to NAVSHIPS for required action.

If an equipment failure occurs on materials provided by BIW, they will prepare an analysis of the failure and determine corrective action will be demonstrated by further tests. A similar procedure will be followed for maintainability demonstrations. If changes are proposed for the shipboard propulsion system, these changes will be incorporated in the PS/LBTS and verified prior to being committed to the entire class.

Schedule

In order to log 500 hours of operating time on the propulsion plant, it has been determined that 6 months of operation will be required. The 500 hours of operation was a goal to be accomplished prior to DSARC III; however, if the laboratory's experience of 6 months is an accurate estimate of time required for 500 hours of operation, something less than that will be logged when DSARC convenes. This limitation has been recognized by OPTEVFOR, and a tentative agreement with them has been reached for purposes of validating the plant sufficiently for DSARC. The overall schedule for the PS/LBTS is identified in Figure IV-2.

Costs

The total cost estimate for the PS/LBTS is 16 million

SCHEDULE

COMPLETE PHASE I DESIGN	JUNE 73
COMPLETE PHASE II DESIGN	FEB 74
BEGIN FABRICATION OF PS	FEB 74
COMPLETE FACILITIES MOD.	OCT 74
COMPLETE PS INSTALLATION	NOV 74
COMPLETE CHECK OUT	DEC 74
LIGHT*OFF	JAN 75
DSARC III	MAY 75
RELIABILITY TESTING	SEP 76

FIGURE IV-2

dollars. This figure represents an order of magnitude and is for purposes of description rather than an accurate estimate of the expected cost.

Chapter V

SIMULATOR

Technical Support

The propulsion system simulator would consist of three major components. The student console will represent the ships operating console to the extent possible. From this component the student will manipulate the controls and instruments to the same degree he would aboard ship. The controls will duplicate the controls of the propulsion plant; however, rather than activating the actual hardware they will become input to a computer. An instructors console will also be provided which has the capability of interrupting the students console by causing casualties similar to those resulting from a malfunctioning propulsion plant. The instructors console will also become input to the computer. The computer or data processing center will receive the two signals and provide its signal to the student with information to the instructor. When the student takes corrective action the results of the action will be reported via the computer to the instructor.

The design of the simulator system should be accomplished by the same contractor that is responsible for the propulsion system. Therefore BIW's contract would require their controls contractor to perform this function, in this case General Electric Apollo. BIW/GE would completely integrate the simulator and provide it to the government agent for installation and testing. A liaison between G&C and GE would be required since the configuration of the students console should closely represent the actual shipboard equipment to the extent that maintenance could be performed.

Facilities for the simulator could be located in a number of places; however, for comparison purposes and for purposes of establishing an expertise within the Navy for the PF propulsion system control console NAVSECPHILADIV will be selected. Accordingly Phily will provide the site, office space, utilities, test plan, installation, construction and all other services necessary for the operation of the simulator. The installation and assembly techniques are of minor importance; however, valuable information relative to the check out procedures and quality control of the shipboard console are certainly pertinent.

The suggested duration of the simulator operation for purposes of supporting a production decision for follow ships is somewhat arbitrary. As a suggestion sufficient time to attest to the first crew training should be adequate for DSARC III. In this regard since the start date for the prototype approach was June 1973 and DSARC III is May 1975 a maximum target time of 23 months seems reasonable.

Integrated Logistic Support (ILS)

<u>Maintenance Planning</u> - The maintenance planning should be provided for a minimum of 7 months. The possibility exists that this simulator and perhaps others can be used to train future PF crews; however, for purposes of this analysis training beyond a favorable DSARC III decision is excluded.

<u>Support and Test Equipment</u> - No special test and support equipment is anticipated for support of the simulator. Any special equipment needed for the non shipboard equipment (i.e. instructors console and computer) will be provided by the laboratory.

Supply Support - Under a contract similar to the SSD contract, BIW would provide all parts for 90 days of operation. Beyond this period NAVSECPHILADIV would provide replacement parts. The laboratory will keep records relative to the shipboard console in a manner similar to what is being done for the prototype approach.

Transportation and Handling - BIW will provide handling instructions prior to installation and is responsible for transportation to the site. The laboratory will see to it that the simulator is moved to the final location and it is accountable after delivery to the site.

Technical Data - Technical data, instructions, repair manuals, and other documentation necessary to operate and maintain the simulator equipment will be made available to NAVSECPHILADIV by BIW. NAVSECPHILADIV will arrange to provide whatever documentation is necessary to support the equipment they provide. Installation procedures, check out procedures, operation procedures and all documentation required under the contract between BIW their subs and the Navy will be made available.

Facilities - NAVSECPHILADIV will provide the facilities for the simulator including any special electrical power requirements and laboratory space.

Personnel and Training - Naval personnel will be provided to the laboratory to observe the lab. technicians during the initial check-out procedure. Subsequent to this checkout the student sailors will gain hands-on experience under the direction and supervision of laboratory instructors. NAVSECPHILADIV will develop a course outline and will conduct the PF and USN training program.

Logistics Support Resources Funds - The resources needed for ILS will be included in the NAVSECPHILADIV budget. The funds required to support the training effort for the simulator are not included in the PF full scale development phase.

Logistic Support Management Information System - The information system for the development of the simulator is primarily an informal effort. Quarterly situation reports are to be developed and sent to the program office for review. Design reviews will be conducted at the subcontractors plant at designated times during the simulator design.

Test and Evaluation

The overall operation and maintenance of the simulator is the responsibility of NAVSECPHILADIV. The test plan and agenda will be developed by the laboratory and the simulator operating procedures will be developed by BIW. The simulator will be completely checked out in every detail by the laboratory prior to being made available to the sailors for operational experience. Operational difficulties will be reported to NAVSHIPS with a summary indicating if the problem relates to the propulsion system integration aboard ship.

If a failure occurs on the simulator, BIW will prepare an analysis of the failure and determine the corrective action to be taken. Verification of the corrective action will be demonstrated by further tests. Changes which are proposed for the shipboard console will first be verified on the simulator prior to being incorporated on the ship console.

Schedule

The simulator schedule will be developed around the time frame established for the full scale prototype. Further identification of milestones is unnecessary for purposes of this study.

Costs.

The total estimated cost for one simulator is three million dollars. This figure represents an order of magnitude and is developed exclusively by the author.

Chapter VI

ANALYSIS

Having described the two alternatives in Chapter IV and V, this Chapter will analyze these alternatives comparing them to the objectives for the PS/LBTS to determine if they have been satisfied. If the alternative fails to satisfy the objective, the objective will be reviewed to determine the impact. The degree that each alternative satisfies the schedule will also be considered and will be followed by a decision analysis. The purpose of the decision analysis is to suggest a method for determining the extra cost associated with the full scale prototype. This analysis together with the differences between the alternatives in relation to their capability of meeting the objectives will provide insight into the cost of this additional information.

Primary Objectives - The primary objective is to support a production decision for the propulsion system in the follow on ships of the PF class. The prototyping approach will provide the greatest confidence that the propulsion system will function as intended. The engines have been tested by the vendor and Litton Industries who are installing them on the Spruance Class destroyers (DD 963). Litton is also providing a Land Based Test Site to attest to the claimed performance of the GE engines and their reliability. The Litton site is similar in configuration to the PF site however the Litton equipment is committed to the last ship of the class. The DD 963 plant will include the same engines; however, the reduction gear and controls are different from the PF system. The engines (i.e. GE LM 2500) have also been operated at sea on the USS ADM Callaghan with a total operating time of approximately 2500 hours.

The PF reduction gear is peculiar to the PF as is the control system. PF will also have a CRP propeller hub and dummy blades on the end of the shaft for purposes of demonstrating pitch change. The reduction gear is a new lightweight design with synchronized clutches. The Navy has been providing reduction gears in ships for many years and no unusual problems are expected to develop here. There will be a few distinctive features such as the specialized temperature sensors in the bearings and the special gear case security and clutching systems; however, all of these features have been to sea at one time or another and little difficulty is expected.

The shafting and propeller hub is a departure from normal practice since the shaft is hollow and incorporates hydraulic lines which are capable of manipulating the controllable pitch propeller. This system is currently being installed on another Navy destroyer and will be tested at sea. The PS/LBTS will verify nominal hydraulic pressure fluctuations but in a unloaded condition. The dummy blades will be capable of changing pitch as the shaft rotates and this will be demonstrated at the LBTS.

The control system is the heart of the entire plant and features the same equipment which will be used on board the ship. This will also be a true test of the propulsion system; and, the primary contribution of the PS/LBTS in supporting the follow on ship production decision.

The fuel system, lub system, and other auxiliaries will not use the same equipment as is intended for the ship since the LBTS will begin construction before the auxiliaries are designed. The duct design will have the same configuration as the ship, however, it will be somewhat

shorter due to the limited height of the building. This is not expected to have any significant effect on the engine performance.

Since the simulator consists mainly of the propulsion system control system, we would not be able to verify the design of the engines, gear, propeller, ducting, auxiliaries and other systems. Each of the systems will be tested at the factory prior to being delivered to the Lead Ship, or in some cases, will have already been tested at sea. The control system is unique and can be considered a significant risk area. The question centers around whether or not a simulator of the control system will adequately relax the technical uncertainty associated with the equipment. One of the more obvious advantages to the simulator is, casualties can be programmed by the instructor very easily, without running the risk of damaging a 16 million dollar plant. Another advantage is that down time on a simulator would not interfere with a reliability test which could be very costly. Also sailor operation can be practiced to the extent of becoming a reflex action without having to operate the total plant. This is particularly important in today's environment of high fuel costs and the potential air pollution. Finally once the simulator approach is proven other simulators can be produced at a lower cost to train crews all over the country.

If asked the initial question, will a simulator support a production decision for follow on ships, I would have to answer, yes. The major risk area of the PF propulsion system is not the power plant but the control system. The engines and propeller either have been or will be sent to sea for testing which is by far a more severe test than the LBTS will provide. The engines are also undergoing extensive testing for

the DD 963 class ships. The auxiliary equipment is not the same as will be installed on the ship and the ductwork has been previously modeled to describe the expected flow patterns.

Secondary Objectives - Of the eleven objectives described on page 3 the total system prototype will satisfy most of them. In terms of the simulator most of the objectives are satisfied when they relate to the control consoles. I will evaluate the alternatives of each of these objectives in the paragraphs that follow; the numbers represent the objectives identified on page 3

1. The propulsion system design is most completely verified with the system which will be built at Philadelphia (i.e. the prototype). This approach will not totally satisfy the objective in that the fuel oil transfer system, fuel oil service system, and lube oil system are to be provided on the bsis of equipment which is available to meet the schedule. The LBTS design precedes the lead ship design by approximately one year and the equipment for these systems have a lead time in excess of one year. They were not identified as long lead items until too late. The simulator can only provide information relative to the control console design which is of paramount importance but very limited in terms of the propulsion system total plant.

2. The verification of initial component check out and test procedures for the drive train and the controls is possible with the prototype. Much of the drive train consists of equipment which is common to all propulsion systems. The engine check out and test procedures are available from other testing efforts, and the control console will be available for check out in the simulator alternative.

3. Verification of installation procedures can be accomplished only on a very selective basis. The total prototype system is more able to accomplish this objective than the simulator approach; however, in each case only a limited amount of information will be available. The information which will be available is more related to the technique used for alignment of the drive train; however, this may not be characteristic of the ship installation due to the restricted space normally available within a ship's engine room.

4. It is conceivable that the prototype can be used as a configuration control baseline for the ships. If this is pursued, the likelihood of determining system reliability must be compromised since it will result in an interruption of the test. Only configuration control of the control console is possible with the simulator approach; however, this change control is unlikely to interfere with the other secondary objectives since they are being verified by other testing programs.

5. The evaluation of selected maintenance procedures is another highly selective objective. Since the LBTS is not spacially the same environment as the ship, the value of the information gained is questionable. Engine maintenance can be verified; however, we can obtain this information from the Litton test since the engines are identical and the acoustic chambers they rest in are very similar. It would be desirable to verify the maintenance procedures on the reduction gear and this will not be possible with the simulator. In terms of the control system whatever can be accomplished on the prototype can also be accomplished on the simulator.

6. Logistic support can be verified to a large extent using the prototype and this is almost completely absent in the simulator approach. ILS will be provided on the propulsion system control console using the simulator.

7. The adequacy of the propulsion controls can be almost completely satisfied by both alternatives. The prototype does have a distinct advantage in that it interfaces with the actual hardware.

8. Machine monitoring information cannot be determined with the simulator. On the ship the control console will be manned at all times. The drive train is not monitored on a ship which is constrained by crew size, it is very important to determine the level of machinery monitoring necessary. Some information will be available from other testing (i.e. DD 963, USS Callighan); however, it may not be relative to the PF.

9. The operating procedures for a normal mode of operation is more accurately determined with the prototype. The procedures for a casualty mode are more accurately determined by a simulator. Potential problems with the prototype due to operator errors could be very costly and possibly defeat the LBTS primary objective.

10. Evaluations of propulsion changes to shipboard systems prior to commitment to the entire class can be accomplished for the prototype system more completely than the simulator alternative.

11. The prototype system will provide a continual input to the PF test and evaluation; however, once the lead ship has been to sea the ship itself will serve as a better standard. The LBTS may serve as a test stand to resolve problems but only if it is representative of the

ships propulsion. The test agent (NAVSECPHILADIV) must be funded to maintain a current baseline.

Comparison of the Objectives:

To a large extent the objectives are met with each alternative in varying degrees. The full scale prototype approach will meet most of the objectives as expected. The simulator will meet the objectives related to the control system, which is perhaps the highest technogolical risk area. In order to determine the significance of these statements, a closer look at the objectives is necessary.

Certainly the primary objective is of paramount importance since failure to support a production decision would effectively halt further consideration of Gas Turbine engines as the means to propell the PF. Testing in terms of the PF engines is currently underway, reduction gears have been successfully built on every ship in the U.S. Navy, and the CRP is also currently undergoing tests at sea. The auxiliary systems are not being modeled with the equipment to be used aboard ship so we can only attest to their functional operation. These systems are also common to all Navy ships with the possible exception of nuclear vessels. The primary departure in relation to the PF is in the area of the control system. The technical uncertainty can be relaxed in this area with either alternative; however, the prototype is more characteristic of the actual propulsion system. Given that each alternative can be used to satisfy the primary objective; what alternative should be selected? What is the cost of this information and to what extent is the technical uncertainty relaxed? The cost and schedule issue will be addressed in a decision analysis after the secondary objectives have been discussed.

In order to deal more thoroughly with the secondary objectives, I have categorized them into three main subdivisions.

1. Objectives Satisfied by Prototype

2. Objectives Satisfied by Either Alternative

3. Objectives Satisfied Partially by the Simulator

It should be apparent that neither of these classifications are all inclusive; however, there is merit in approaching the discussion from this view. Figure VI-1 is a matrix which identifies the objectives and how they relate to the major subdivisions. The objectives are described on page 3

1. The full scale prototype as described for the PF, PS/LBTS is best able to verify the basic design of the propulsion plant; however, the verification is primarily one of determining that the physical interfaces have been resolved. Installation procedures are partially verified but procedures which the shipyard will use to install the equipment will vary, based upon the facilities which are available at the yard doing the construction. Some useful alignment information may be forthcoming; but, this means little in relation to the alignment within the bowels of the ship which more accurately describes the problem of the shipbuilder. It is certainly desirable to have hardware which can be used as a configuration control baseline; however, this can only have a detrimental effect on reliability testing and operational training. Objective number 10 alludes to proposed changes of the shipboard propulsion system which is perhaps a restatement of configuration control (i.e. evaluate proposed changes before commitment to the entire class). Finally in relation to the continual input into the PF

SECONDARY OBJECTIVES MATRIX

ALTERNATIVE → / ↓ OBJECTIVE	SATISFIED BY PROTOTYPE	SATISFIED BY BOTH	SATISFIED BY SIMULATOR
1	X		
2			X
3	X		
4	X		
5			X
6			X
7		X	
8			X
9		X	
10	X		
11	X		

FIGURE V-1

test and evaluation, I would suggest that the lead ship and follow ships provide a better basis for test and evaluation.

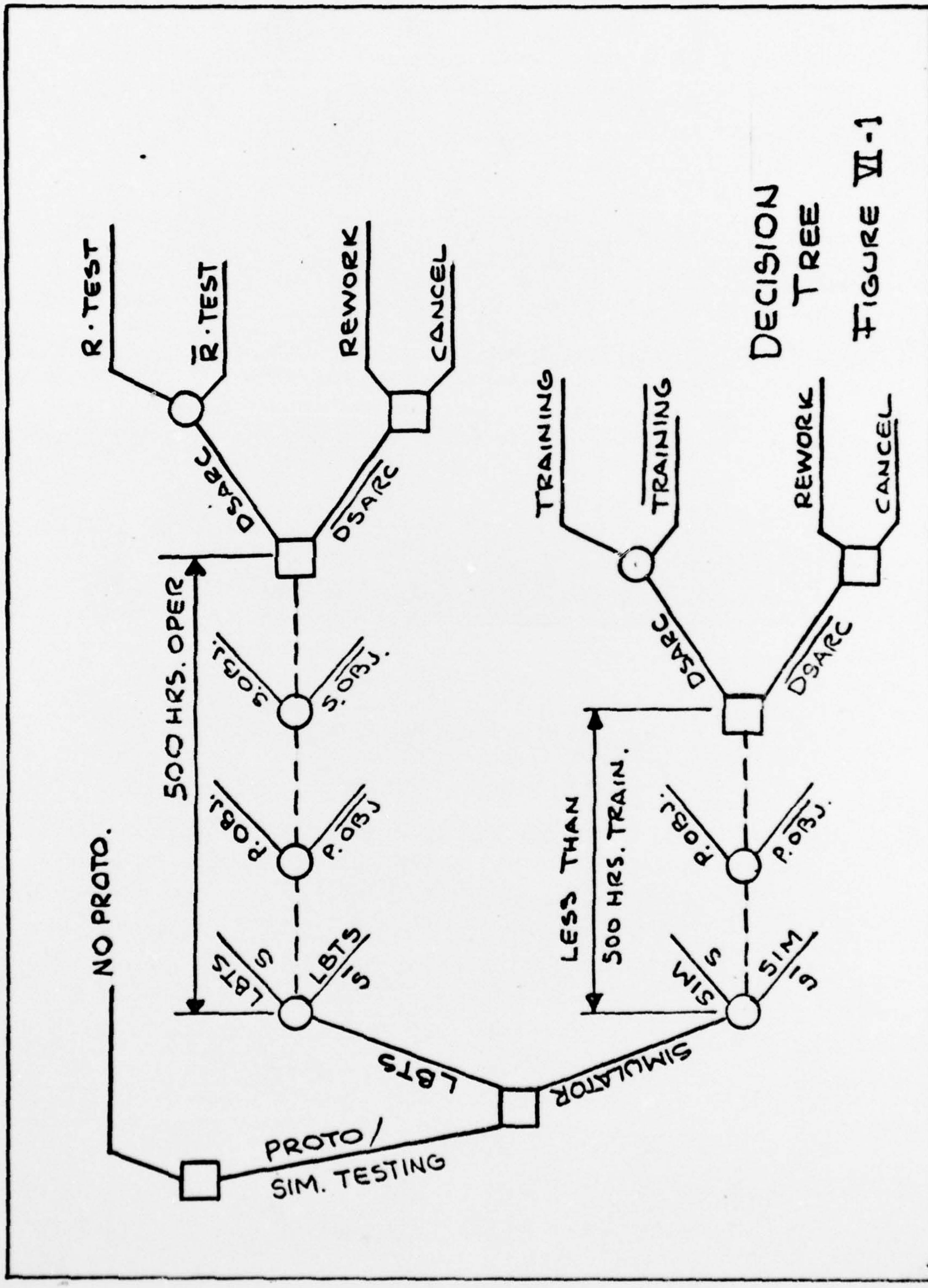
2. The adequacy of the propulsion controls can better be determined with the prototype system in relation to the system response time; however, beyond this the advantages of the simulator become more desirable. Consider the cost and schedule risk associated with an operating error in judgement of the prototype system. The ease with which the operating procedures for both normal and casualty modes can be verified on the simulator have the advantage of permitting rapid crew training with a minimal down time. Once the simulator has been developed others can be (inexpensively) built to permit backfitting improvements without interfering with the crew training.

3. Component and check out procedures can be verified with the prototype system, however, this type of information is also available to a limited extent from the Litton plant and the USS Callaghan. Maintenance procedures and logistic support requirements are also available from the tests in varying degrees. The validity of maintenance procedures is limited since the LBTS does not duplicate the tight work spaces which are characteristic of destroyer type ships. Information relative to the level of machine monitoring can be provided from the Litton Company and at sea trials which are underway. Finally this information which is extracted from other sources in conjunction with a simulator will attest to all but the reduction gear validation.

The question of schedule often drives costs and judgement. In the case of the prototype current information indicates considerable schedule risk is associated with the LBTS if it is to be used as the

primary basis for a favorable DSARC III decision relative to the propulsion system. Difficulties have been experienced with getting under contract early enough to order forgings, shafting, controls and other equipment. The schedule risk is relaxed considerably with the simulator alternative; since the numbers of equipment are less, and the degree to which we must precede the lead ship design to develop the LBTS, which is characteristic of the plant to be used on the ship is relaxed. The simulator offers a much better opportunity of meeting the scheduled DSARC III date.

The decision tree in Figure VI-1 represents the major events which are likely to result in fulfilling the primary objective of supporting a decision at DSARC III for the PF propulsion system. The secondary objectives have been added to the prototype alternative since most of them may be achieved during the first 500 hours of test operation. There is only one objective for the simulator alternative; that of supporting the production decision. I will not attempt to quantize this analysis since this would require developing estimates of the simulator which are unavailable. The major point to be made here is, if the program were to be marketed on the basis of developing a prototype; the likelihood of success is much reduced when compared to the simulator. This will be particularly true if the marketing of this approach included a promise to attain the secondary objectives as well. The simulator alternative makes no such claim. It is based upon reducing the technological uncertainty with the propulsion console and using current testing to satisfy the other objectives.



DECISION TREE

FIGURE VI-1

Chapter VII

CONCLUSIONS AND SUMMARY:

Overview - In retrospect the validity of entering into full scale prototyping for the propulsion system centers around the need for testing in order to relax any technical uncertainty which may be inherent in a system. The need for testing is normally recognized; however, it is sometimes difficult to determine how much testing is adequate. As an example, we must be in a position to determine, with some degree of accuracy, how much testing is needed to obtain the desired system reliability. This judgement needs to be tempered with the recognition that designed-in reliability, laboratory reliability, and operational reliability normally result in three separate sets of figures.

Programs which are sold during the various LSARC milestones on the basis of a prototype system which may have a high schedule risk stand a good likelihood of overall program slips. The difficulty which exists in obtaining equipment when it is needed for the prototype before the system has been totally designed are often far riskier than entering directly into production. Lesser testing efforts can more directly relate to recognized technical uncertainty, as in the case of the simulator, and may equally satisfy the program requirements with less schedule impact at reduced costs.

Problems also develop when conflicting objectives are imposed upon the test operation. An example would be operator testing requirements being imposed when reliability testing is being satisfied. If reliability testing is of paramount importance, any objective which would tend to interfere with reliability would compromise one, or both desired

outcomes. Recognition of conflicting test objectives is necessary very early in the program to avoid making promises which are impossible to fulfill. This problem can be partially overcome by first identifying a need for testing on the basis of some technological problem; and then developing a test which will demonstrate the system capability. There is a strong desire to stretch the testing effort as far as possible by including other objectives to a system test which may interfere with the original requirement.

Criteria - The criteria presented here are not extensive but are sufficient to demonstrate that it is necessary to give considerable thought to testing prior to implementing a test program. Directives such as DODD 5000.1 often identify requirements which are taken at face value and tend to put the question of "NEED" in a subordinate role. It is hoped that these criteria will stimulate serious consideration and rigorous planning in responding to directives of this type.

Prior to entering a test program, it must be demonstrated that a significant technical problem exists, and this problem must be described in engineering terms. If this cannot be done, it may be difficult to assess when the goal has been achieved, or if achievement is possible. An exception to this approach is (possible) in the basic research area; however, as relates to development the first statement of establishing the "NEED" seems fundamental.

Having decided that a test program is necessary, some recognition is required relative to the risk associated with achieving the proposed test configuration. This must take into account the problems which may develop in obtaining the equipment and its support on schedule and at

cost. Many times in a development contract the test design is leading the system design; so it is very possible to begin testing a system which bears little resemblance to the system representing the end product. Because of the accelerated testing efforts, which will support development, the schedules are often compressed resulting in a greater risk of success than would exist if the test were deleted and we went directly into the development phase of the contract.

The desire to demonstrate capabilities over and above the original need for testing can result in a proliferation of requirements which defeat our purposes. If reliability of a system is to be demonstrated, an added requirement for maintainability will compromise the reliability goal. Under these conditions, perhaps what is really desired is a demonstration of availability which is a function of both reliability and maintainability. Great care must be taken in selecting the objectives.

Prior to formulating the test program, a thorough review of the on-going testing in the same area is essential. It may be difficult to justify testing for system A when similar tests are currently being conducted for system B. Also there is no reason to believe that program A will be more successful than program B for testing the same component.

A rigorous analysis of all available alternatives should be made to determine the advantages and disadvantages of each. This should be followed by a decision analysis which will describe the cost of the information associated with each alternative. As a corollary to this approach, insight can be gained relative to conflicting requirements such as the proliferation of objectives.

Full consideration must be given to the ILS needed for the program early and an understanding by all as to what we expect the test results will disclose. What information will be collected and who will evaluate the results should also be identified.

After the test program has been described and the location for the testing is determined, some assessment of the management risk must be identified. The people who will manage the test effort seldom measure productivity by the same standards as the program office. They may have the same values in terms of getting the job done; however, they are oriented differently and respond to different measures of effectiveness.

As a final consideration, the politics in terms of the overall program should be looked at. An example of this might be to consider who will chair the DSARC decision points. This consideration should be looked at in relation to time. What is the likelihood of the people in power remaining in power and supporting your program when the information you have generated must be evaluated by them? Who will be their replacement and what is likely to be their point of view?

Having completed this study, I am certain of only one thing. The problem I have described here represents part of the visible portion of an ice-berg. The possible uses for this study are perhaps threefold. It may prove useful for future program managers to consider these elements as a way of looking at the decision to be made in relation to testing programs. The system analysis approach to the problem of prototyping will not yield solutions but will identify considerations not normally investigated. Decision analysis can be a useful tool in making judgement decisions. This is an indicator of the cost of information, and will

result in a good check list.

Summary - The research question which I intended to describe was to identify criteria which could be used in determining the desirability of entering into a prototyping program. The criteria I have identified are as follows:

1. Justify the prototype in engineering terms.

2. Assess the cost and schedule risk associated with having a successful prototype test in terms of the benefits.

3. Select objectives with extreme care.

4. Review ongoing testing for applicability.

5. Analyze all possible alternatives.

6. Consider ILS early in the test program.

7. Determine the management risk associated with the organization that will do the testing.

8. Consider the political issues which may prevail at critical decision points.

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LIST OF ACRONYMS AND ABBREVIATIONS

BIW	Bath Iron Works Corporation
BJCO	Bird Johnson and Company
DOD	Department of Defense
DSARC	Defense Systems Acquisition Review Council
G&C	Gibbs and Cox Company
GE	General Electric
ILS	Integrated Logistics Support
LBTS	Land Based Test Site
LOP	Local Operators Panel
MCC	Master Control Console
NAVSEC	Naval Ship Engineering Center
NAVSHIPS	Naval Ship Systems Command
NAVSECPHILADIV	Naval Ship Engineering Center Philadelphia Division
PS/LBTS	Propulsion System/Land Based Test Site
PF	Patrol Frigate
PMS399	PF Project Office
SSD	Ship System Design
T&E	Test and Evaluation
NRPO	Naval Regional Procurement Office
CNT	Chief of Naval Training
RMA	Reliability, Maintainability, Availability
OPTEVFOR	Operational Test and Evaluation Force